

Miniaturized Thermal Acoustic Gas Sensor Based on a CMOS Microhotplate and MEMS Microphone [†]

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Abstract: In this work, we present a novel thermal acoustic gas sensor, fabricated using a CMOS microhotplate and MEMS microphone. The sensing mechanism is based on the detection of changes in the thermal acoustic conversion efficiency which is dependent on the physical properties of the gas. The gas sensor has all the benefits of CMOS technology, including low cost and miniaturization. Here, we demonstrate its application for CO₂ gas detection.

Keywords: thermal acoustic; gas sensor; CMOS; MEMS

1. Introduction

Thermal acoustic systems are used to generate acoustic waves in gases. A typical system consists of a thermally modulated wire or thin film used to kinetically excite gas molecules [1]. To maximize the thermal-acoustic conversion efficiency, it is important to minimize the thermal mass of the heated element.

Thermal acoustic systems have been used as loudspeakers and as components in systems to convert thermal acoustic power into electrical energy [2], however, little work has been done to study their application as gas sensors. The sensing mechanism studied in this work relies on the fact that the thermal acoustic conversion efficiency is partly dependent on the physical properties of the gas, namely its thermal effusivity.

The widespread adoption of sensors has been accelerated due to the use of CMOS (complementary metal-oxide-semiconductor) fabrication processes which offer excellent manufacturability, low cost, and low power consumption [3]. We have exploited CMOS technology in the design of our thermal acoustic sensor, which utilizes a miniature CMOS based microhotplate and MEMS (micro-electromechanical system) microphone. We demonstrate the application of the sensor for CO₂ gas sensing.

2. Fabrication and Results

Figure 1a shows an image of the microheater chip which consists of a 4.6 μm -thick SiO₂ membrane (600 μm in diameter) with an embedded tungsten micro-heater (300 μm in diameter). The microheater incorporates a poly-silicon thermodiode for temperature monitoring. An analogue MEMS microphone (TDK (Japan), model ICS-40300) is used as the acoustic detector. To enable efficient acoustic coupling, the microheater chip is mounted above the port of the microphone. A cylindrical cavity (dimensions: 600 μm in diameter \times 375 μm in height) is formed between the microheater and microphone port, with an inlet to allow gas to permeate. A second microphone is used as a reference channel, to enable compensation for ambient noise. A schematic diagram of the sensor is shown in Figure 1b and an image of the fabricated device is shown in Figure 1c.

Gas tests were performed in a metal gas cell, with the sensor exposed to CO₂, diluted with zero grade air. The microheater was electrically modulated with a sinusoidal voltage and the microphonic signals were amplified and digitized using a National Instruments data acquisition instrument. A software-based lock-in amplifier was used to process the microphonic signal to help remove noise. The response of the sensor to various CO₂ exposures is shown in Figure 1d. The sensor could easily be integrated with a conventional acoustic gas detector (which uses a microphone to detect the sound of a gas leak), in order to provide additional information regarding gas concentration.

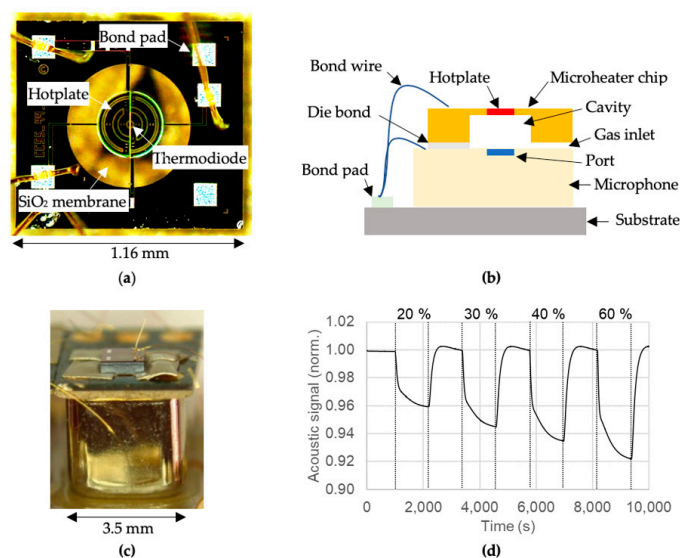


Figure 1. (a) Optical image of the microheater chip used for the thermal acoustic gas sensor; (b) schematic diagram showing the sensor construction; (c) image of the fabricated sensor; (d) response to various CO₂ gas concentrations.

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